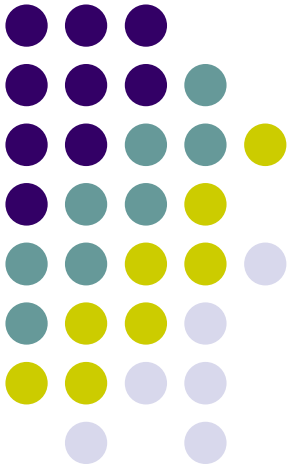
Mineral Sampling

Copper extraction



Terminologies

- **Acidic**: Acidic solutions turn blue litmus red due to the presence of hydrogen ions.
- **Alkaline**: Alkalis are strong bases that turn red litmus blue due to the presence of hydroxyl ions.
- **Attachment**: The bonding of a particle to an air bubble after a collision.
- **Chalcopyrite**: A copper iron sulfide mineral that is brassy yellow in colour. The formula is $CuFeS_2$
- **Collision**: a mineral particle bumps into a bubble. Mineral particles may also collide with other mineral particles and with water molecules.
- **Detachment**: A mineral particle separates from the air bubble that it was attached to.
- **Gangue (pronounced gang)**: The unwanted and worthless materials in an ore deposit. Two common examples are quartz and calcite. A separation process is needed to separate the valuable minerals from the gangue.

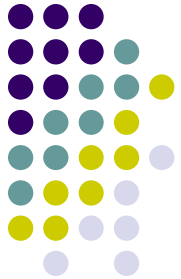
Terminologies

- **Hydrophilic**: water -loving
- **Hydrophobic**: water-hating
- **Hydrocarbons**: Molecules containing only carbon and hydrogen atoms.
- **Lime**: The name given to chemicals that can be derived from calcium carbonate (limestone). Quicklime is Calcium Oxide. Slaked lime is Calcium Hydroxide.
- **Ore**: A mixture of ore minerals and gangue minerals. An ore contains a collection of minerals that can be mined for profit.
- **Processing**: The separation of ore minerals from gangue minerals producing a concentrate of the ore and tailings (a concentrate of the gangue minerals)
- **Rehabilitation**: The process whereby areas disturbed by mining are restored to what they were previously or to another agreed land use.
- **Sphalerite**: This zinc sulfide mineral is also known as Black Jack. It has the formula ZnS.
- **Stockpiling**: Ore which has been mined is built into piles on the mine site, ready for crushing and processing. These piles are called stockpiles.

Separation methods

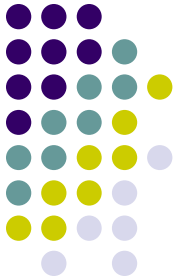
- The types of methods used in the mineral industry to segregate media:
  - Pre-concentration (ore sorting)
  - Heavy Media Separation (“sink-float”)
  - Gravity methods
  - Magnetic concentration
  - Electrostatic concentration
  - Froth flotation

Copper production



- **1. Mining, Crushing**
  The beginning for all copper is to mine sulfide and oxide ores through digging or blasting and then crushing it to walnut-sized pieces.
- **2. Grinding**
  Crushed ore is ball or rod-milled in large, rotating, cylindrical machines until it becomes a powder usually containing less than 1 percent copper. Sulfide ores are moved to a concentrating stage, while oxide ores are routed to leaching tanks.
- **3. Concentrating**
  Minerals are concentrated into a slurry that is about 15% copper. Waste slag is removed. Water is recycled. Tailings (left-over earth) containing copper oxide are routed to leaching tanks or are returned to the surrounding terrain. Once copper has been concentrated it can be turned into pure copper cathode in two different ways: Leaching & electrowinning or smelting and electrolytic refining.
- **4a. Leaching**
  Oxide ore and tailings are leached by a weak acid solution (typically H_2SO_4), producing a weak copper sulfate solution.

Copper production



- **5a. Electrowinning (SX/EW)**
  The copper-laden solution is treated and transferred to an electrolytic process tank. When electrically charged, pure copper ions migrate directly from the solution to starter cathodes made form pure copper foil. Precious metals can be extracted from the solution.

  OR
- **4b. Smelting**
  Several stages of melting and purifying the copper content result, successively, in matte, blister and, finally, 99% pure copper. Recycled copper begins its journey to finding another use by being resmelted.
- **5b. Electrolytic Refining**
  Anodes cast from the nearly pure copper are immersed in an acid bath. Pure copper ions migrate electrolytically from the anodes to "starter sheets" made from pure copper foil where they deposit and build up into a 300-pound cathode. Gold, silver and platinum may be recovered from the used bath.

Copper production

- **6. Pure Copper Cathodes**
  Cathodes of 99.9% purity may be shipped as melting stock to mills or foundries. Cathodes may also be cast into wire rod, billets, cakes or ingots, generally, as pure copper or alloyed with other metals.

- **7. Cathode is converted into:**

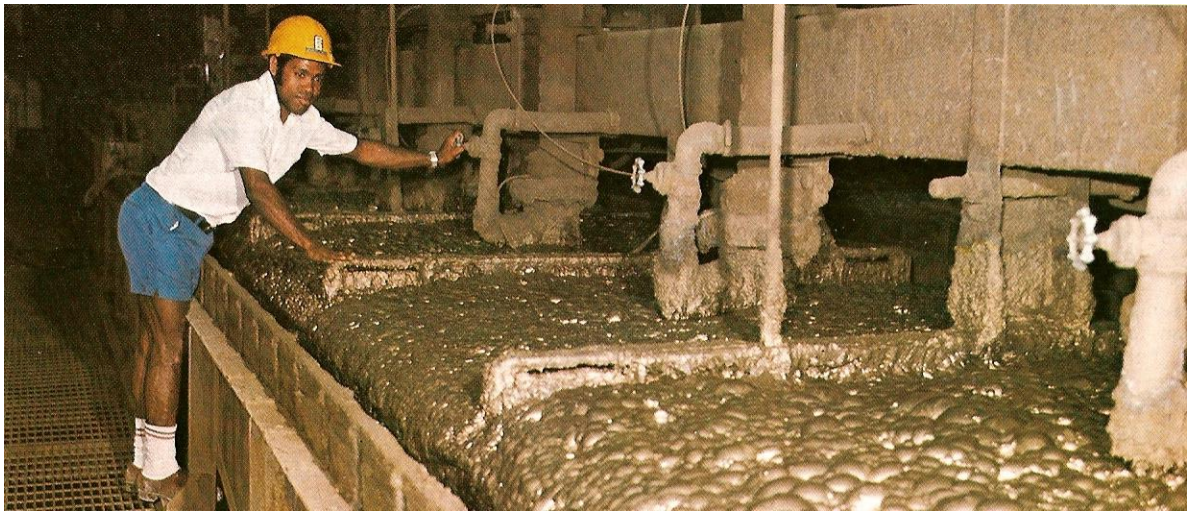
  - **Wire Rod** - Coiled rod about 1/2" in diameter is drawn down by wire mills to make pure copper wire of all gages.

  - **Billet** - 30' logs, about 8" diameter, of pure copper are sawed into these shorter lengths which are extruded and then drawn as tube, rod and bar stock of many varied sizes and shapes. Rod stock may be used for forging.

  - **Cake** - Slabs of pure copper, generally about 8" thick and up to 28' long, may be hot- and cold-rolled to produce plate, sheet, strip and foil.

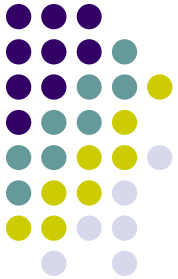
  - **Ingot** - Bricks of pure copper may be used by mills for alloying with other metals or used by foundries for casting.

Copper flotation



Copper being recovered by froth flotation at Bougainville Copper Mine. Chemicals are added to cause the sulphide minerals to float while the unwanted siliceous material sink to the bottom of the tanks.

Copper flotation



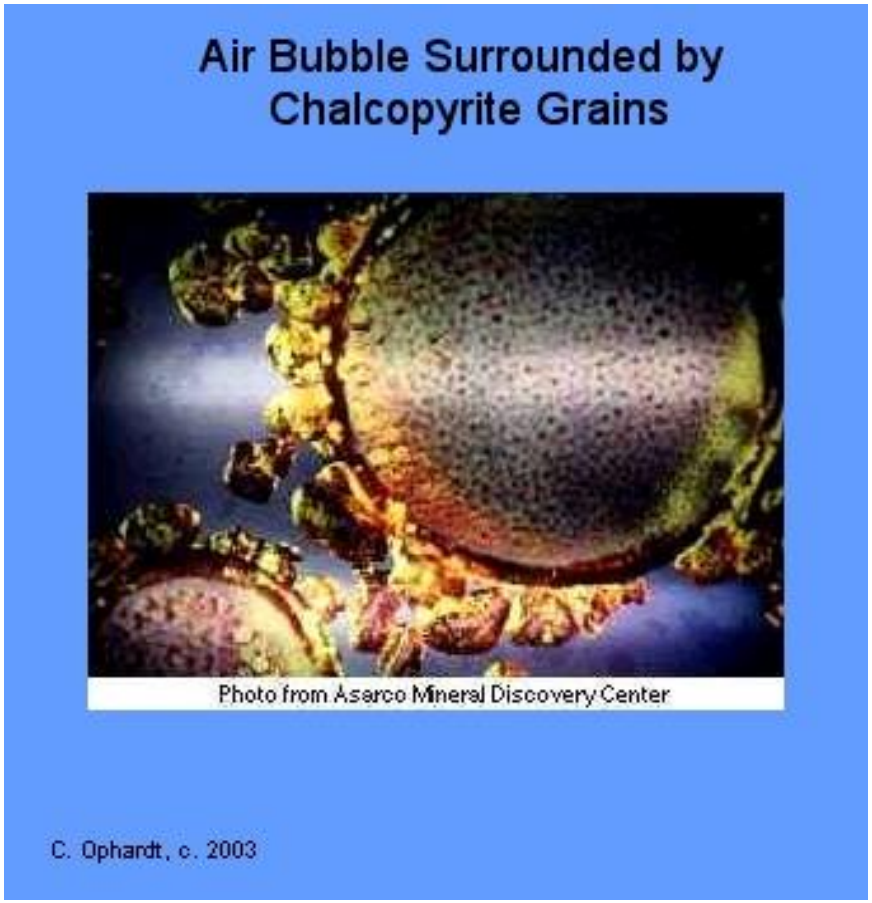
- Flotation depends on:
  - Grains of some minerals (and especially of metals) differ in the degree to which their surfaces can be wetted by a suitable solution.
  - The powdered product of grinding the ore is fed into a series of tanks called flotation cells which are filled with a solution containing various oils capable of forming a froth.
  - Air is pumped into each cell, the solution being agitated to bring froth of bubbles to the surface.
  - In the case of copper minerals, the particles adhere to the froth, which is separated from the remainder of the unwanted material (‘gangue’), which sinks to the bottom of the tanks.
  - By varying the chemical conditions within the cells, different results can be obtained, hence making froth flotation a highly selective process.

Copper flotation

- Chemicals used in copper flotation include:

Collector	Sodium isobutyl xanthate (SIBX), potassium amyl xanthate (PAX)
Frothers	Methyl isobutyl carbinol (MIBC), Pine oil
pH	6.5 – 7.5
pH control	Lime (Calcium Hydroxide)
Minerals floated	Chalcopyrite, silver, galena, sphalerite

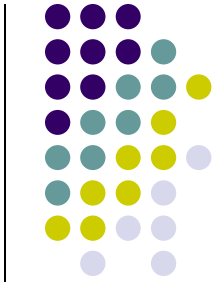
Copper flotation



- **Air Bubble:**
  The graphic on the left shows an air bubble surrounded by grains of chalcopyrite that has been coated with xanthate. The pine oil acts as a frother only, providing the air bubbles that the xanthate sticks to.

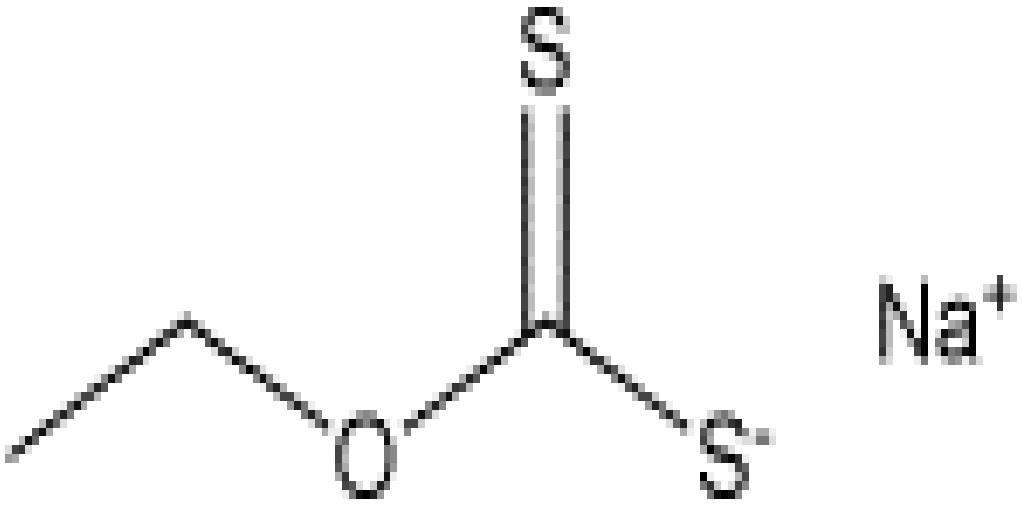
  (Text edited by Rob Vugteveen, Director, Asarco Mineral Discovery Center)

Copper flotation



- How does it work?
  - The xanthate molecule tends to be a long chained hydrocarbon (5 carbons if it's a amyl xanthate).
  - One end of the chain is polar (i.e. water-like or hydrophilic) whilst the other end is non-polar (i.e. non water-like or hydrophobic).
  - The polar end of the xanthate sticks to the sulphide mineral, whilst the non-polar end is attracted to non-polar species in the flotation cell, such as pine oil or MIBC.
  - Pine oil (or MIBC) are hydrocarbons that are added as frothing agents.
  - The pH is kept between 6.5 and 7.5 as this causes the polar end of the xanthate to ionize in the solution and preferentially stick to the chalcopyrite mineral whilst leaving the pyrite mineral behind.
  - Air is pumped into the tanks and agitated, causing the chalcopyrite grains to surface and flow over the edge of the tank.
  - The gangue minerals remain at the bottom of the tanks and are discarded in tailing ponds.

Copper flotation

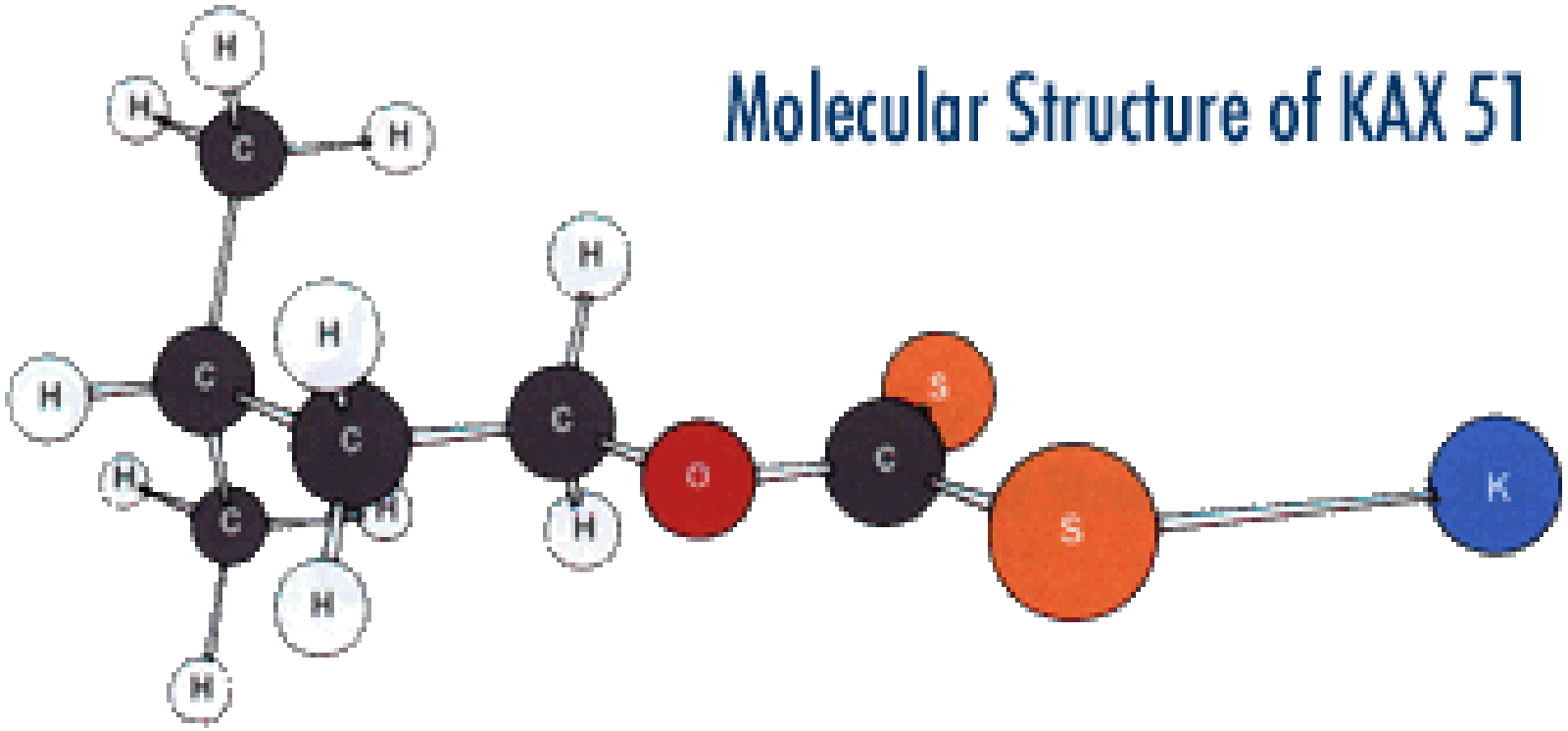


Sodium Ethyl Xanthate (SEX)

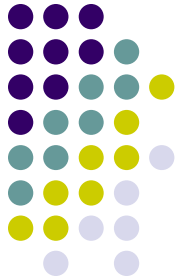
$C_3H_5NaOS_2$

Copper flotation

Potassium Amyl Xanthate (PAX):



Parameters that can influence



- Parameters that can influence flotation performance/recovery:
  - Particle size
  - Chemical reagents used
  - Concentration of reagents
  - Slurry density
  - pH
  - Degree of agitation
  - Rate of air bubble generation

References

- Hunter/ Simpson/ Stranks, ‘Chemical Science’, Science Press, Sydney, p.435 (diagram), 1980
- Oresome Froth, Minerals Council of Australia, www.minerals.org.au/education
- http://www.copper.org/education
- http://www.elmhurst.edu/~chm/vchembook/332flotation.html